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Evaporative Emissions of Gross Liquid Leakers in MOBILE6

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Evaporative Emissions of Gross Liquid Leakers in MOBILE6

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ABSTRACT

In six previous documents (M6.EVP.001, M6.EVP.002, M6.EVP.004, M6.EVP.005, M6.EVP.006, and M6.EVP.008), EPA noted that a potentially significant portion of evaporative emissions may be the result of a small number of vehicles leaking liquid gasoline (rather than gasoline vapors). This document describes this approach and EPA's proposed estimates of both the frequency of occurrence vehicles with significant leaks of liquid gasoline and the magnitude of the emissions from those leaks.

Please note that EPA is seeking any input from stakeholders and reviewers that might aid us in modeling any aspect of resting loss or diurnal evaporative emissions.

Comments on this report and its proposed use in MOBILE6 should be sent to the attention of Larry Landman. Comments may be submitted electronically to mobile@epa.gov, or by fax to (734) 214-4939, or by mail to "MOBILE6 Review Comments", US EPA Assessment and Modeling Division, 2000 Traverwood Drive, Ann Arbor, MI 48105. Electronic submission of comments is preferred. In your comments, please note clearly the document that you are commenting on, including the report title and the code number listed. Please be sure to include your name, address, affiliation, and any other pertinent information.

This document is being released and posted. Comments will be accepted for sixty (60) days. EPA will then review and consider all comments received and will provide a summary of those comments, and how we are responding to them.

Table of Contents

Appendices

*** **DRAFT** ***

Evaporative Emissions of Gross Liquid Leakers in MOBILE6

Report Number M6.EVP.009

Larry C. Landman
U.S. EPA Assessment and Modeling Division

1.0 Introduction

In four recently released draft reports **[1,2,3,4]*** the US Environmental Protection Agency (EPA) noted that for some vehicles, the primary mechanism of evaporative emissions was the substantial leakage of liquid gasoline (as opposed to simply vapor leaks). In each of those reports, such vehicles were referred to as "gross liquid leakers." One consistent feature of these vehicles is that their evaporative emissions far exceed the evaporative emissions of the vehicles that were not gross liquid leakers. In this report, EPA will:

- develop a set of criteria to define "gross liquid leakers,"
- determine the evaporative emissions produced by these "gross liquid leakers," and
- determine the occurrence (i.e., frequency) of these "gross liquid leakers" as a function of vehicle age.

2.0 Characterizing "Gross Liquid Leaker"

The term "gross liquid leaker" identifies vehicles having substantial leaks of liquid gasoline, as opposed to simply vapor leaks. But, this term has been used in different contexts and it is, therefore, likely that some vehicles that behave as "gross liquid leakers" based on one type of evaporative emissions test might not behave as "gross liquid leakers" on another type of test. In this analysis, EPA makes use of four different types of testing programs to identify those vehicles with substantial liquid leaks:

- a real-time diurnal (RTD) test **[1,2]** in which evaporative emissions are measured for stabilized test vehicles that

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* The numbers in brackets refer to the references in Section 4 (page 25).

are enclosed in a sealed housing with the temperatures cycling over a 24-hour period to simulate the pressure-driven evaporative HC emissions that result from the daily increase in ambient temperature,

- a hot soak test **[3]** in which evaporative emissions are measured for one hour following a driving cycle for test vehicles that are enclosed in a sealed housing,
- a running loss test **[4]** in which evaporative emissions are measured during a driving cycle for test vehicles that are enclosed in a sealed housing, and
- a visual inspection **[5]**.

In this report, EPA first estimates the mean evaporative emissions of these "gross liquid leakers" for each type of test (Section 2), and then estimates the likelihood of those types of leaks occurring (Section 3).

Generally, when EPA predicts evaporative emissions (either resting loss, diurnal, hot soak, or running loss*) these two variables are critical:

1) the ambient temperature and

2) the fuel volatility as measured by the Reid vapor pressure (RVP) of the test fuel.

However, for vehicles that are classified as "gross liquid leakers," most (but, not necessarily all) of the evaporative emissions are the result of the leak of liquid gasoline. Since it is unlikely the rate of leakage is a function of either the temperature or the fuel volatility, EPA proposes treating the evaporative emissions of these vehicles as independent of ambient temperature and RVP.

An additional source of data was a 1998 test program conducted for the Coordinating Research Council (CRC) in which 50 late-model year vehicles (1992 through 1997, with a mean age of 4.5 years) were tested using the hot soak, running loss, and RTD tests.**[6]** However, none of those 50 vehicles had detected liquid leaks. Thus, the results from these tests were not used in the analyses in Section 2. The observation that no "gross liquid leakers" were identified among this sample of 50 vehicles will be considered in the analysis in Section 3.

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* MOBILE6 will not consider "gross liquid leakers" in its estimates of evaporative emissions from crankcase losses or refueling. The methodology for estimating these emissions has not changed from that in MOBILE5.

2.1 "Gross Liquid Leakers" on the RTD Test

The category of vehicles identified as "gross liquid leakers" was first discussed in a report dealing with evaporative emissions during resting losses and diurnals. In that report, the term "gross liquid leaker" was used to refer to vehicles which had resting loss emissions of at least 2.0 grams per hour. The analyses in that report were based on tests in which the ambient temperature cycled over 24 hours to simulate (in real-time) a full day's temperature pattern. The results of those real-time diurnal (RTD) tests were used to estimate both resting loss and diurnal emissions. Those analyses were performed on 119 vehicles tested in various EPA programs plus 151 vehicles tested for the Coordinating Research Council (CRC). **[1]**

Since the 151 vehicles in the CRC program were randomly recruited (within each of three model year ranges), EPA proposes to use that random sample to estimate the means of the resting loss and diurnal emissions of vehicles that had liquid leaks of gasoline. The mechanics who inspected the test vehicles identified 32 of those vehicles as having evidence of some fuel leakage (from damp hoses and connectors to visible leaks).

Since our intention is to only estimate the mean of the emissions of the vehicles having only substantial leaks (i.e., "gross liquid leakers"), we first limited our sample to vehicles:

1.) whose resting loss emissions (i.e., the mean emissions during the last six hours of the 24-hour RTD test) were at least 0.25 grams per hour and

2.) whose total RTD emissions were at least 30 grams per day.

These limitations produced a set of vehicles whose gasoline leaks had an observable effect on the evaporative emissions (even if that effect was not sufficient to create a "gross liquid leaker"). Eleven such vehicles were found among the 32 having identified liquid leaks. The emissions from those 11 vehicles are given in Appendix A. It is important to note that while all of these vehicles leaked liquid gasoline, less than half of them were eventually classified as "gross liquid leakers" (i.e., having resting loss emissions of at least 2.0 grams per hour). All of these 11 vehicles are carbureted. In the absence of evidence to the contrary, EPA proposes to treat fuel injected and carbureted vehicles with liquid leaks the same for the purposes of resting loss and diurnal emissions.

The usual approach that EPA has followed in estimating emission levels is to simply calculate the mean of the sample of applicable test results. However, the number of vehicles identified as "gross liquid leakers" (i.e., having resting loss emissions of at least 2.0 grams per hour) is relatively small, and the range of their emissions is relatively large. From a statistical standpoint, the combination of these two conditions may lead to a high degree of uncertainty in the calculated mean. An alternate approach is to fit an assumed type of distribution curve to those limited number of observations. The type of distribution that has historically been used for emissions is the lognormal distribution **[7]** (i.e., the logarithms of the emissions, rather than the emissions themselves, are assumed to be normally distributed). EPA proposes to use this approach.

Prior to modeling the estimated diurnal emissions, we reexamined the data in Appendix A. Since our intent was to model the distribution of diurnal emissions from vehicles with the severest leaks, we dropped from the analysis the results of vehicle number 9042 due to its relatively low diurnal emissions (suggesting that it was not a "gross liquid leaker" relative to its diurnal emissions). Additionally, we assumed that if a valid estimate of the diurnal emissions from vehicle 9129 been obtained*, then that estimated diurnal would have been less than the emissions from the two highest emitting vehicles but higher than the emissions from the remaining eight vehicles. Using these two assumptions, we ranked the diurnal emissions and assigned a percentile to each. The plot of those percentiles versus the corresponding diurnal emissions is given in Figure 2-1, on the following page. The solid line in that figure is the graph of the cumulative distribution obtained by assuming that the logarithms of the emissions are normally distributed. (The mean of the logarithms of the emissions is 3.812; the corresponding standard deviation is 1.075.) (Distributions other than the lognormal were examined, but none came as close to approximating the observed distribution.) We then used that lognormal distribution to estimate the frequency associated with each possible diurnal emission level.

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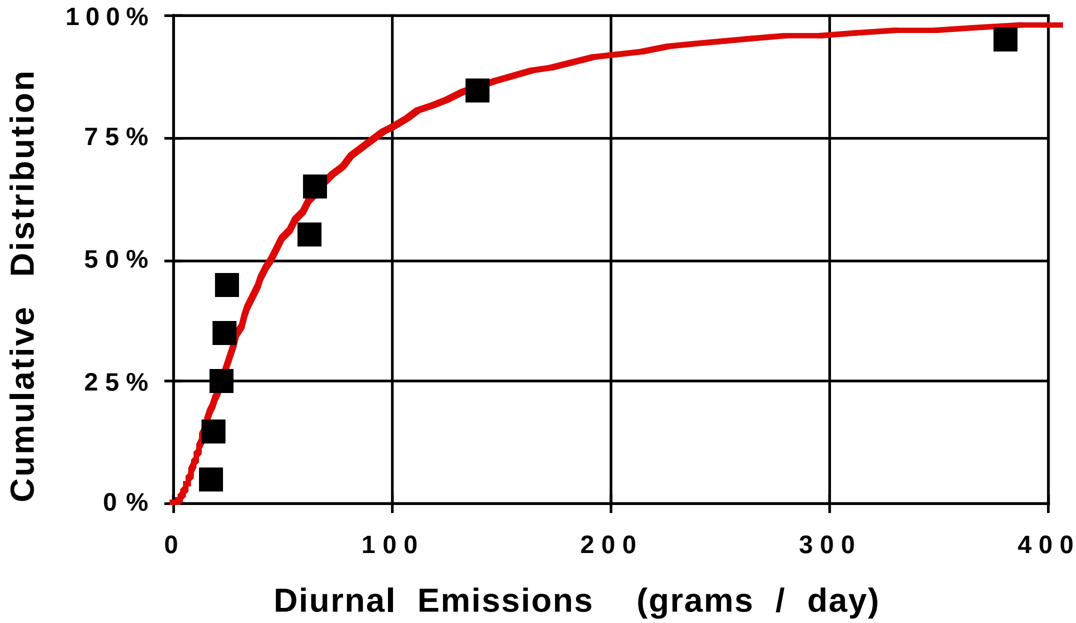
* In Reference **[1]**, EPA noted that the hourly diurnal emissions from vehicle number 9129 suggest that the leak actually developed around the tenth hour of the test. Hence, that vehicle was a "gross liquid leaker" for only the second half of the RTD test. Trying to precisely estimate the emissions during the first half of the RTD test, assuming the vehicle had been a "gross liquid leaker" for the entire test, is questionable. However, based on the vehicle's emissions for the last 14 hours of the RTD, it appears that its 24-hour RTD emissions would have fallen between vehicles number 9054 and 9087.

Figure 2-1

Cumulative Distribution of Estimated Diurnal Emissions
For Vehicles Exhibiting Liquid Fuel Leaks
With Diurnal Emissions Over 15 grams per day



Although the lognormal distribution predicts that a small number of vehicles would have impossibly high diurnal emissions, EPA chose to limit the maximum emissions based on the assumption that a truly severe leak would result in the vehicle being quickly repaired. Since one (real world) test vehicle (in our sample) had diurnal emissions of almost 400 grams per day, EPA assumed that the limit of the maximum emissions should be higher than that value. EPA proposes using 1,000 grams per day as the maximum for the purpose of estimating fleet averages.

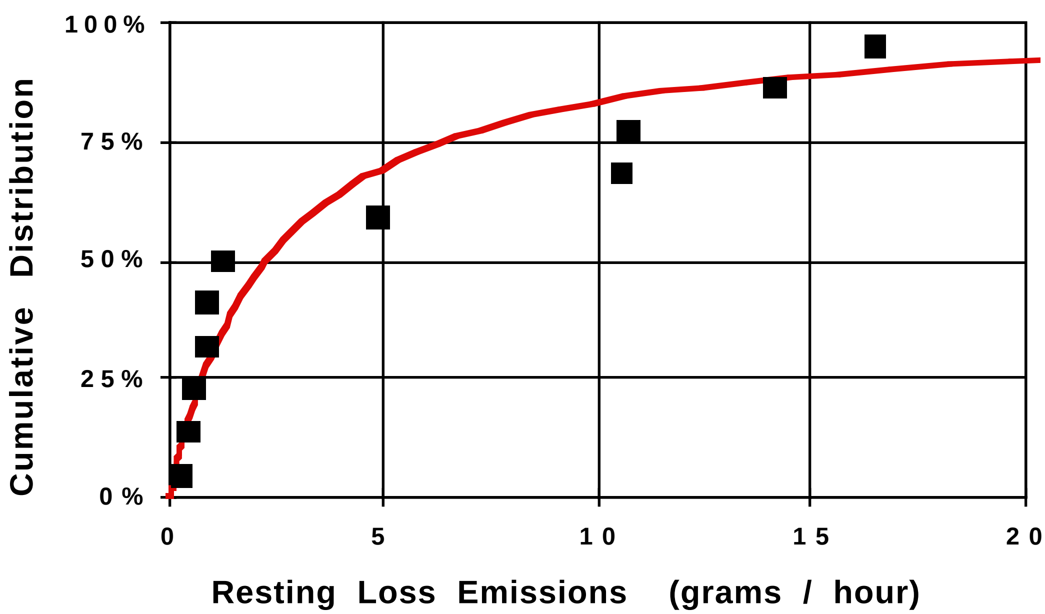
The lognormal distribution also predicts that some leaking vehicles will have diurnal emissions of close to zero. To separate the "gross liquid leakers" from vehicles having only minor or moderate leaks, we again examined the estimated diurnal emissions in Appendix A. A visual inspection of those data indicated a relatively large discontinuity (i.e., a break) from 24.86 to 62.64 grams per day. Based on that observation, EPA proposes using 25 grams per day as the minimum value. For a group of leaking vehicles whose diurnal emissions were between 25 and 1,000 grams per day, the lognormal distribution predicts that the mean diurnal emissions of that group of leakers would be 104.36 grams per day. (Doubling the maximum possible diurnal to 2,000 grams per day would result in increasing the estimated group average only to 107.41 grams daily.)*

EPA proposes to use 104.36 grams per day as the average full-day's diurnal emissions from "gross liquid leakers" over a day for which the maximum daily temperature is exactly 24°F above the daily low temperature. (See report number M6.EVP.002 to use temperature cycles with ranges other than 24°F.) Earlier versions of MOBILE limited the pressure driven leaks (i.e., diurnal emissions) to times when the ambient temperature was at least 40°F. However, we suspect that, at temperatures below 40°F, the diurnal emissions would still continue. However, at those low temperatures, the likelihood of ozone exceedences would be small.

The preceding approach was repeated (using the data in Appendix A) for resting loss emissions. The resting loss emissions from the 11 vehicles in Appendix A are plotted below in Figure 2-2.

Figure 2-2

Cumulative Distribution of Resting Loss Emissions
For 11 Vehicles Exhibiting Liquid Fuel Leaks
And Having Resting Loss Emissions Over 0.25 grams / hour



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* The more traditional approach would have been to simply average the diurnal emissions of the four vehicles in Appendix A having RTD emissions of at least 100 grams with the diurnal emissions of two other leakers from the EPA testing programs. The mean of those six diurnals is 100.29 grams per day, which corresponds to using the lognormal distribution with the maximum diurnal emissions set to 675 grams per day.

As with the previous figure (Figure 2-1), the solid line in Figure 2-2 is the graph of the cumulative distribution obtained by assuming that the logarithms of the resting loss emissions are normally distributed. (The mean of the logarithms of the resting loss emissions is 0.841; the corresponding standard deviation is 1.528.) A visual inspection of that figure suggests that the lognormal model does not fit the resting loss emissions of leaking vehicles as well as it fit the diurnal emissions. In fact, a straight line (i.e., a "uniform" distribution) is the curve that best fits the resting loss emissions for vehicles having at least 1.0 grams per hour.

In previous analyses (see M6.EVP.001), EPA determined that the lower bound of the resting loss emissions of the gross liquid leakers would be 2.0 grams per hour. Since one (real world) test vehicle (in our sample) had resting loss emissions of about 16 grams per hour, EPA assumed that the limit of the maximum emissions should be higher than that value. EPA proposes using 50 grams per hour as the maximum for the purpose of estimating fleet averages. For a group of leaking vehicles whose hourly resting loss emissions were between 2.0 and 50 grams, the lognormal distribution predicts that the mean resting loss emissions of that group of leakers would be 9.163 grams per hour.* (Doubling the maximum possible resting loss to 100 grams per hour would result in increasing the estimated group average only to 10.875 grams hourly.) The linear fit (i.e., uniform distribution) predicts the mean of the resting losses from vehicles emitting at least 2.0 grams per hour would be 10.518 grams per hour. Thus, all of those approaches produce similar estimates of the average hourly resting loss emissions from "gross liquid leakers."

Although the uniform distribution produces a superior estimate of the observed data compared to the lognormal distribution, both approached produce similar estimates of the mean resting loss emissions. Therefore, EPA proposes to use the lognormal distribution for consistency among the various evaporative models in this report. EPA proposes to use the estimate based on the lognormal model (i.e., 9.16 grams per hour) as the average hourly resting loss emissions from "gross liquid leakers." Since the mechanism responsible for the vast majority of the resting loss emissions from these vehicles is the fuel leaking out of the vehicle, and since this process is not dependent upon the ambient temperature or fuel volatility, EPA had

* The more traditional approach would have been to simply average the resting loss emissions of the five vehicles in Appendix A having resting loss emissions of at least 2.0 grams per hour with the resting loss emissions of two other leakers from the EPA testing programs. The mean of those seven resting losses is 8.84 grams per hour, which corresponds to using the lognormal distribution with the maximum hourly resting loss emissions set to 45.2 grams per hour.

proposed (see reference [1]) considering resting loss emissions from "gross liquid leakers" as independent of fuel volatility and temperature.

2.2 "Gross Liquid Leakers" on the Hot Soak Test

The category of vehicles identified as "gross liquid leakers" based on evaporative emissions during a hot soak, was discussed in a report prepared for EPA by one of its contractors (see the third footnote on page 1). In that report, the term "gross liquid leaker" was used to refer to "vehicles which produce abnormally high evaporative emissions as a result of a fuel leak and which have hot soak emissions of over 10 grams per test." Since the hot soak test is one hour in duration, "grams per test" is equivalent to "grams per hour" for the hot soak. (See reference [8] to calculate hot soak emissions for time periods less than an hour.)

In the analyses for that report, hot soak test results on 493 vehicles were used. Of those 493 vehicles, the mechanics identified 14 as having evidence of some fuel leakage (from damp hoses and connectors to visible leaks). Those 14 vehicles (along with their hot soak test results) are listed in Appendix B. The hot soak emissions of those 14 leaking vehicles ranged from 2.00 to 88.57 grams per test (averaging 22.47 grams). For the remaining 479 vehicles that did <u>not</u> have detected liquid leaks, their hot soak emissions ranged from 0.04 to 88.35 grams per test (averaging 1.77 grams).

A quick inspection of the emissions listed in Appendix B suggests that the port fuel injected (PFI) vehicles that have leaks exhibit higher hot soak emissions that the carbureted (CARB) vehicles that have leaks. Since the fuel delivery systems in the PFI vehicles operate at a higher pressure than do the systems in the carbureted vehicles, a hole in the fuel system of a PFI vehicle will leak more fuel than a hole of the same size in a carbureted vehicle.* Therefore, the observation that the PFIs with liquid leaks have (on average) higher hot soak emissions than the corresponding carbureted vehicles is reasonable. There was an insufficient sample of leaking vehicles with throttle body injection (TBI) systems to analyze. Therefore, the hot soak emissions from this technology grouping will be estimated using a theoretical rather than statistical approach.

In Figure 2-3 (on the following page), we plotted the hot soak emissions (in grams per test) of the six carbureted vehicles (from Appendix B) versus the corresponding percentiles. The solid line in that figure is the graph of the cumulative distribution obtained by assuming that the logarithms of the emissions are

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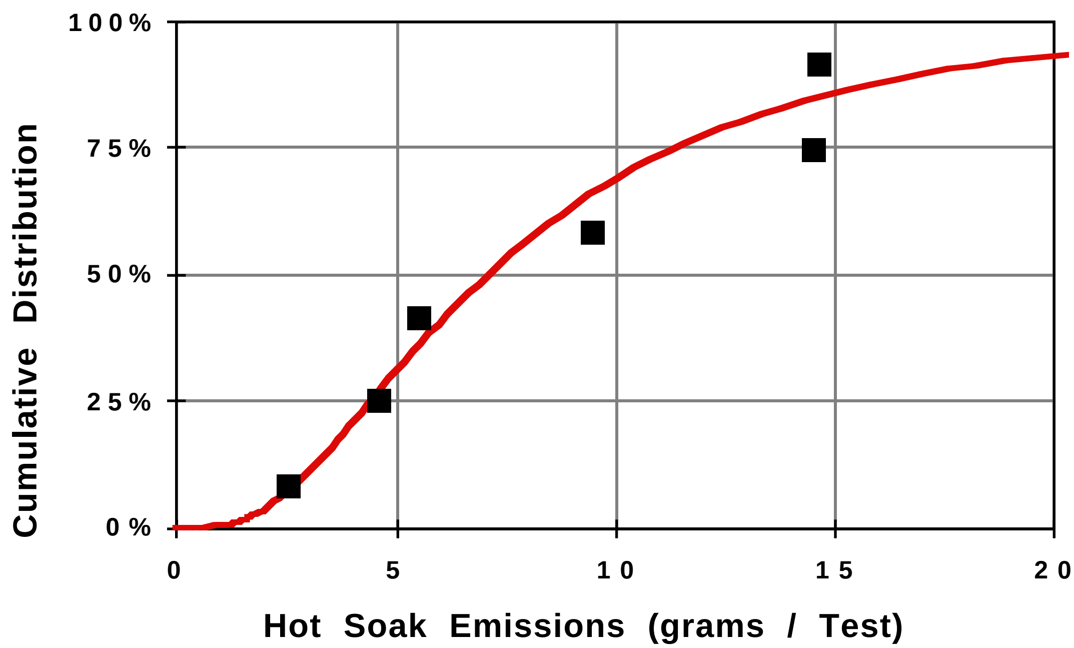
* Bernoulli's equation indicates that the leak rate will be proportional to the square root of the ratio of operating pressures.

normally distributed. (The mean of the logarithms of the hot soak emissions is 1.9644; the corresponding standard deviation is 0.6963.) As was done in Section 2.1 with diurnal emissions, that lognormal distribution was used to estimate the frequency associated with each possible hot soak emission level. Although the lognormal distribution predicts that a small number of carbureted vehicles would have impossibly high hot soak emissions, EPA chose to limit the maximum emissions based on the assumption that a truly severe leak would result in the vehicle being quickly repaired. In Appendix B, we can see that one owner tolerated a vehicle having hot soak emissions of almost 90 grams per test. Based on that observation, EPA will assume that, for the purpose of estimating the mean hot soak emissions, the hot soak emissions of the "gross liquid leakers" range between 10 and 300 grams per test.

Figure 2-3

Cumulative Distribution of Hot Soak Emissions
For 6 Carbureted Vehicles Exhibiting Liquid Fuel Leaks

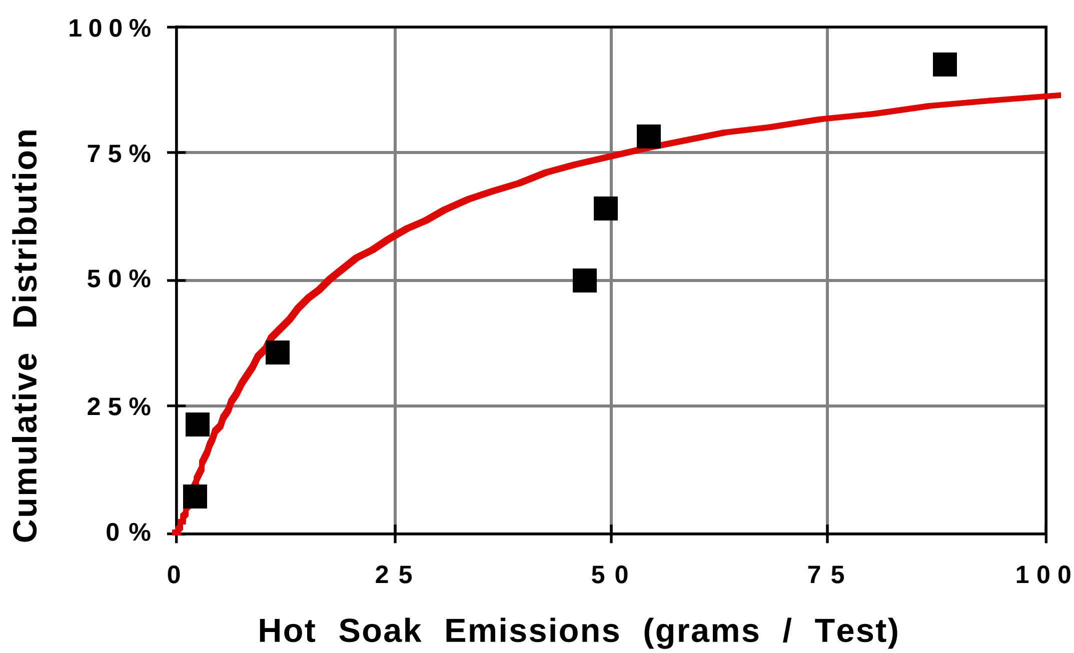


Using the lognormal distribution in Figure 2-3, we can predict the mean hot soak emissions for the "gross liquid leaking" carbureted vehicles assuming hot soak emissions ranging between 10 and 300 grams per test. The mean hot soak emissions of that group of leakers would be 16.9549 grams per test (or per hour). (That average emission level was not very sensitive to the assumption of the emissions of the highest possible leaker. Lowering the assumed level of the highest emitting carbureted vehicle to 50 grams reduced the average only to 16.5503. Similarly, raising the assumed level of the highest emitting vehicle to 1,000 grams increased the average only to 16.9550.) EPA, therefore, proposes using 16.95 grams per test as the estimate of hot soak emissions from "gross liquid leaker" carbureted vehicles.

To estimate the mean of the hot soak emissions from the PFI vehicles that had liquid leaks, we proceeded in the same fashion that we employed for the carbureted vehicles. In Figure 2-4 (on the following page), we plotted the hot soak emissions (in grams per test) of the seven PFI vehicles (from Appendix B) versus the corresponding percentiles.

Figure 2-4

Cumulative Distribution of Hot Soak Emissions
For 7 PFI Vehicles Exhibiting Liquid Fuel Leaks



The solid line in Figure 2-4 (above) is the graph of the cumulative distribution obtained by assuming that the logarithms of the emissions are normally distributed. (The mean of the logarithms of the hot soak emissions is 2.8830; the corresponding standard deviation is 1.5822.) A visual inspection of that figure suggests that the lognormal model does not fit the hot soak emissions of leaking PFI vehicles as well as it fit the carbureted vehicle. In fact, a straight line (i.e., a "uniform" distribution) provides almost as good a fit to the hot soak emissions for the six PFI vehicles having at least 2.25 grams per test. (We are considering the lognormal distribution to be a better fit because the sum of the squares of the residuals is lower than for the linear fit.) EPA proposes to use the lognormal distribution because it is the better fit and for consistency among the various evaporative models in this report.

Using the lognormal distribution in Figure 2-4, we can predict the mean hot soak emissions for the "gross liquid leaking" PFI vehicles assuming hot soak emissions ranging between 10 and 300 grams per test. The mean hot soak emissions of that group of leakers would be 57.1425 grams per test (or per hour). (That average emission level is only slightly sensitive to the assumption of the emissions of the highest possible leaker. Lowering the assumed level of the highest emitting carbureted vehicle to 250 grams reduces the average to 53.3468. Similarly, raising the assumed level of the highest emitting vehicle to 400 grams increases the average only to 63.0990.) The linear fit (i.e., uniform distribution) predicts the mean of the hot soak emissions for PFI vehicles emitting at least 10 grams per test would be 52.2481 grams per test. Thus, all of those approaches produce similar estimates of the mean hourly resting loss emissions from "gross liquid leakers." EPA, therefore, proposes using 57.14 grams per test as the estimate of hot soak emissions from "gross liquid leaker" PFI vehicles.

Due to a lack of data (see Appendix B), we were not able to perform a similar analysis for the TBI vehicles. This situation was addressed in the report on hot soak emissions (M6.EVP.004), in which the author stated:

> "While there is no data on TBI liquid leakers in the data sets, Bernoulli's equation indicates that the leak rate for TBI systems would be about one half that for PFI systems (the square root of the ratio of operating pressures). Therefore, without further data, the author suggests assuming that TBI liquid leakers might emit approximately half the emissions of PFI systems."

EPA proposes to assume that the frequency of having a hole of a given size is the same for both the TBI and PFI vehicles. Based on that assumption, Bernoulli's equation predicts that at each frequency in the cumulative distribution curve for PFIs (i.e., Figure 2-4), the corresponding TBI curve would predict only one-half the hot soak emissions. Thus, if a TBI vehicle were to have leaks in its fuel system sufficient to produce hot soak test emissions between 10 and 300 grams per test, then holes of the same size would result in hot soak test emissions for PFI vehicles ranging between 20 and 600 grams per test. The lognormal distribution predicts that for a sample of PFI leakers whose hot soak test emissions range between 20 and 600 grams per test, the mean hot soak test emissions would be 89.9979 grams per test. Thus, the mean TBIs would have hot soak emissions of one-half of that predicted value which is 44.9990 grams per test. Therefore, EPA proposes using 45.00 grams per test as the estimate of hot soak emissions from "gross liquid leaker" TBI vehicles. [As a test of this approach, we note that the lognormal distribution predicts the median (i.e., 50 percentile) hot soak test emissions of leaking (but not necessarily "gross liquid leaking") PFI vehicles to be 17.8678 grams per test. This would suggest that the corresponding median value for leaking TBI vehicles would be half or 8.9339 grams per test which is quite similar to the actual test result of 8.28 from Appendix B.]

2.3 "Gross Liquid Leakers" on the Running Loss Test

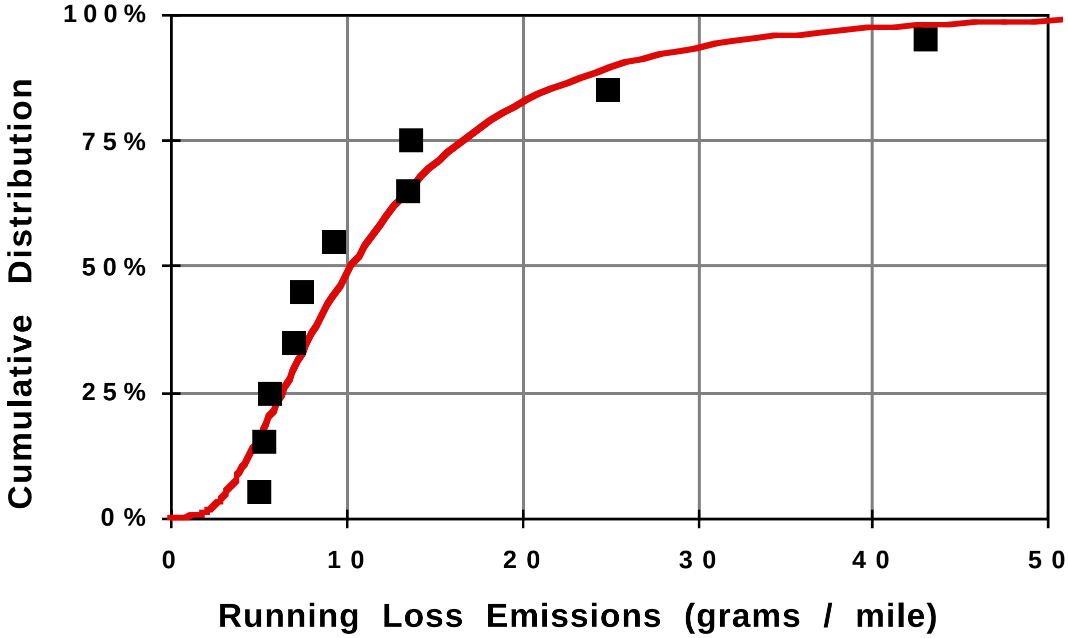
In 1997, running loss tests were performed on 150 vehicles as part of a testing program conducted for the Coordinating Research Council (CRC). The mechanics who inspected those test vehicles identified 40 of those vehicles as having evidence of some fuel leakage (from damp hoses and connectors to visible leaks). The running loss emissions for these vehicles were measured over a single LA-4 driving cycle, using tank fuel (RVP about 6.8 psi), and ambient temperature about 95 degrees Fahrenheit. **[9]**

Since our intention is to estimate the mean of the emissions of the vehicles having only substantial leaks, we first limited our sample to leaking vehicles whose running loss emissions were at least 5.0 grams per mile over the single LA-4 driving cycle. (Five grams per mile appears to be a reasonable break point since the next highest running loss emissions for a leaking vehicle was only 3.52 grams per mile.) Ten such vehicles were found among those 40 having identified liquid leaks. The emissions from those 10 vehicles (reported as grams per mile, grams per test, and grams per hour) are given in Appendix C. It is important to note that while all of these vehicles leaked liquid gasoline, not all of them are classified as "gross liquid leakers" (using the criteria developed in this section). All of these 10 vehicles are carbureted. (Two of the original 40 leaking vehicles were fuel injected; however, their running loss emissions were each less than 0.4 grams per mile.)

The approach used in the preceding sections (for diurnal, resting loss, and hot soak) was repeated for running loss emissions (using the data in Appendix C). The running loss emissions from the 10 vehicles in Appendix C are plotted (on the following page) in Figure 2-5. As with the previous figures, the solid line is the graph of the cumulative distribution obtained by assuming that the logarithms of the emissions are normally distributed. (The mean of the logarithms of the emissions is 4.2; the corresponding standard deviation is 0.88.)

Figure 2-5

Cumulative Distribution of Running Loss Emissions For Vehicles Exhibiting Liquid Fuel Leaks With Running Loss Emissions Over 5 grams per mile



To determine the appropriate range of running loss emissions for these "gross liquid leakers," we reexamined the running loss test results on all 150 vehicles. All of the vehicles that did not have an identified liquid leak had running loss emissions (for the single LA-4 cycle) of less than 4.2 grams per mile. EPA selected 7.0 grams per mile as the value that distinguished between vehicles that have liquid leaks and those defined as "gross liquid leakers." Since one (real world) test vehicle (in the CRC sample) had emissions on the running loss test of about almost 43 grams per mile, EPA assumed that the limit of the maximum emissions should be higher than that value. EPA proposes using 200 grams per hour as the maximum for the purpose of estimating fleet averages. For a group of leaking vehicles whose running loss emissions were between 7.0 and 200 grams per mile, the lognormal distribution predicts that the mean running loss emissions of that group of leakers would be 17.649 grams per mile. (As with the emissions on the hot soak and diurnal tests, that average emission level was not very sensitive to the assumption of the emissions of the highest possible leaker. Lowering the assumed level of the highest emitting carbureted vehicle to 90 grams/mile reduced the average only to 17.181. Similarly, raising the assumed level of the highest emitting vehicle to 500 grams/ mile increased the average only to 17.696.) As previously stated, this analysis of running loss emissions of "gross liquid leakers" is based solely on carbureted vehicles. Using the logic (and Bernoulli's equation) from Section 2.2, it could be argued that the running loss emissions from PFI gross liquid leakers would be four times that amount. However, it does not seem reasonable to assume such a high emissions rate based on no data. Therefore, in the absence of evidence to the contrary, (for the purposes of running loss emissions of "gross liquid leakers") EPA proposes to treat fuel injected and carbureted vehicles the same.

Thus, EPA proposes using 17.65 grams per mile as the estimate of the emissions from a running loss test from ALL "gross liquid leakers" over a single LA-4 driving cycle.

2.4 Summary of Magnitudes of Evaporative Emissions

For the full day diurnal emissions (based on the temperatures cycling over a 24 degree Fahrenheit range) of "gross liquid leaking" vehicles, EPA proposes to use 104.36 grams per day. (See report number M6.EVP.002 to use other temperature cycles or to estimate hourly diurnal emissions.)

For the resting loss emissions of all "gross liquid leaking" vehicles, EPA proposes to use 9.16 grams per hour.

To estimate the result of a hot soak test on "gross liquid leaking" vehicles:

- EPA proposes to use 16.95 grams per test for carbureted vehicles,
- EPA proposes to use 45.00 grams per test for TBI vehicles, and
- EPA proposes to use 57.14 grams per test for PFI vehicles.

To calculate the actual hot soak emissions per hour, the resting loss emissions must be subtracted from the hot soak test emissions.

To estimate the result of a running loss test on all "gross liquid leaking" vehicles, EPA proposes to use 17.65 grams per mile. To calculate the actual running loss emissions, the resting loss emissions must be subtracted from the running loss test emissions.

These proposals are summarized in the Table 2-1 on the following page.

Table 2-1

Summary of Emissions from "Gross Liquid Leakers"

Type of Emissions (in grams)	--- Fuel Delivery System --- Carbureted	TBI	PFI
• Hot Soak Test (per hour)*	16.95	45.00	57.14
• Resting Loss (per hour)	9.16		
• Diurnal (per day)	104.36		
• Running Loss Test (per mile)*	17.65		

* **Both the hot soak and running loss test emissions include resting loss emissions; therefore, the resting loss emissions must be subtracted.**

3.0 Frequency of Occurrence of "Gross Liquid Leaker"

In Section 2, the magnitude of each type of evaporative emissions from liquid leakers was estimated independently using lognormal distributions; however, EPA believes the data can be linked when estimating the frequency of the "gross liquid leakers." Specifically, EPA proposes to make the following two basic assumptions in predicting the frequency of gross liquid leakers:

1.) For each test of evaporative emissions (i.e., RTD, hot soak, and running loss tests), the frequency of gross liquid leakers increases as a function of age only. This model of the frequency is based on the assumption that modern technology vehicles will show the same tendency toward gross liquid leaks as do the older technology vehicles at the same age.* In reference number **[10]**, EPA modifies this assumption for the 1996 and newer vehicles certified to the new enhanced evaporative standard.

2.) The vehicles classified as gross liquid leakers on the hot soak test are the same vehicles identified as gross liquid leakers on either the running loss or RTD tests. (That is, the set of vehicles classified as gross liquid leakers on the hot soak test is the union of the set of vehicles classified as gross liquid leakers on the RTD test with the set of vehicles classified as gross liquid leakers on the

* An alternative approach that EPA is not proposing (due to lack of data) assumes that the modern technology vehicles exhibit a lower tendency to leak (due to the more stringent demands imposed by the new evaporative emissions certification procedure as well as heightened attention to safety, such as, fuel tank protection and elimination of fuel line leaks). This approach would result in replacing each single logistic growth function with a family of two or more curves.

running loss test.) Therefore, the rate of gross liquid leakers as identified on the hot soak test would be the sum of the two rates for the RTD testing and the running loss of the two rates for the RTD testing and the running loss testing minus the number of double counted vehicles (i.e., the product of those two rates assuming these two categories are independent of each other).

EPA considered two different approaches to predict the occurrence of "gross liquid leakers." (See footnote on page 20.)

3.1 First Approach to Estimate Frequency

The first approach involved two basic steps:

1.) Find two logistic growth functions that separately predict the rate of "gross liquid leakers" on the RTD test and on the running loss test, respectively.

2.) Verify that the union of those two functions approximate the results observed on the hot soak test.

3.1.1 First Approach Estimating Frequency of Gross Liquid Leakers on the RTD Test

In the report dealing with evaporative emissions measured during the RTD tests (M6.EVP.001), EPA used the results from a test fleet of 270 vehicles (i.e., the combined EPA and CRC samples) to estimate the occurrence of gross liquid leakers within each of the three model year ranges used in the recruitment process (the pre-1980, 1980-85, and 1986-95 vehicles). The estimated rate of occurrence of the "gross liquid leakers" is reproduced in Table 3-1 (below). The large confidence intervals are the result of the relatively small sample sizes.

Table 3-1

Frequency of Gross Liquid Leakers
Based on RTD Testing

Vehicle Age (years)	Sample Size	Frequency	Standard Deviation	90% Confidence Interval Lower	Upper
6.12	85	0.20%	1.41%	0.00%	2.52%
13.00	50	2.00%	1.98%	0.00%	5.26%
21.79	51	7.84%	3.76%	1.65%	14.03%

* "**Vehicle Age**" was calculated by subtracting the model year from the test year and then adding one-half to simulate the rate as of January first.

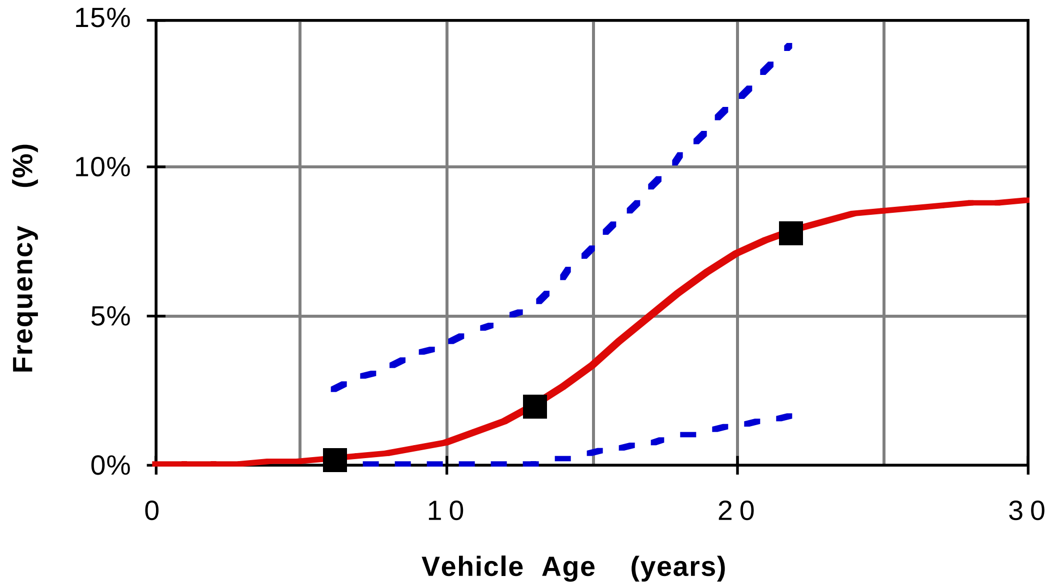
In that earlier report (M6.EVP.001), EPA then derived a logistic growth curve that exactly fit those three data points (from Table 3-1). The equation of that function is given below:

$$\text{Rate of Gross Liquid Leakers Based on RTD/Resting Loss Testing} = \frac{0.08902}{1 + 414.613 * \exp[-0.3684 * AGE]}$$

The predicted occurrences of "gross liquid leakers" based on this equation are given in Appendix D. The frequencies from Table 3-1 are plotted in Figure 3-1 (below). Also graphed in that figure are the 90 percent confidence intervals (as dotted lines) from Table 3-1 and the predicted frequencies (as the solid line) from Appendix D (or from the preceding equation).

Figure 3-1

Predicted Frequency of Gross Liquid Leakers
Based on RTD Testing



After EPA had obtained the equation at the top of this page, additional test data were provided by CRC (project number E-41). Specifically, a test program run during 1998 found no "gross liquid leakers" on the RTD test in a sample of 50 late-model year vehicles (1992 through 1997, with a mean age of 4.5 years). (See reference **[6]**.) Those test results are consistent with the preceding equation.

3.1.2 First Approach Estimating Frequency of Gross Liquid Leakers on the Running Loss Test

For the 150 vehicles in the CRC running loss testing program, the occurrence of "gross liquid leakers" (i.e., the six vehicles in Appendix B whose running loss emissions exceeded 7.0 grams/mile), the occurrence of gross liquid leakers was calculated within each of the three model year ranges used in the recruitment process (the same model year ranges used in the RTD testing). Those estimated rates of occurrence of the "gross liquid leakers" appear below (in Table 3-2). The large confidence intervals are again the result of the relatively small sample sizes.

Table 3-2

Frequency of Gross Liquid Leakers Based on Running Loss Testing

Vehicle Age (years)	Sample Size	Frequency	Standard Deviation	90% Confidence Interval Lower	90% Confidence Interval Upper
8.84	50	2.00%	1.98%	0.00%	5.26%
14.24	39	5.13%	3.53%	0.00%	10.94%
22.48	61	4.92%	2.77%	0.36%	9.47%

It was not possible to exactly fit the frequencies in Table 3-2 with an increasing function (since the observed frequency seem to drop after age 14.24 years). EPA derived a logistic growth curve that best fit those three data points. The equation of that function is:

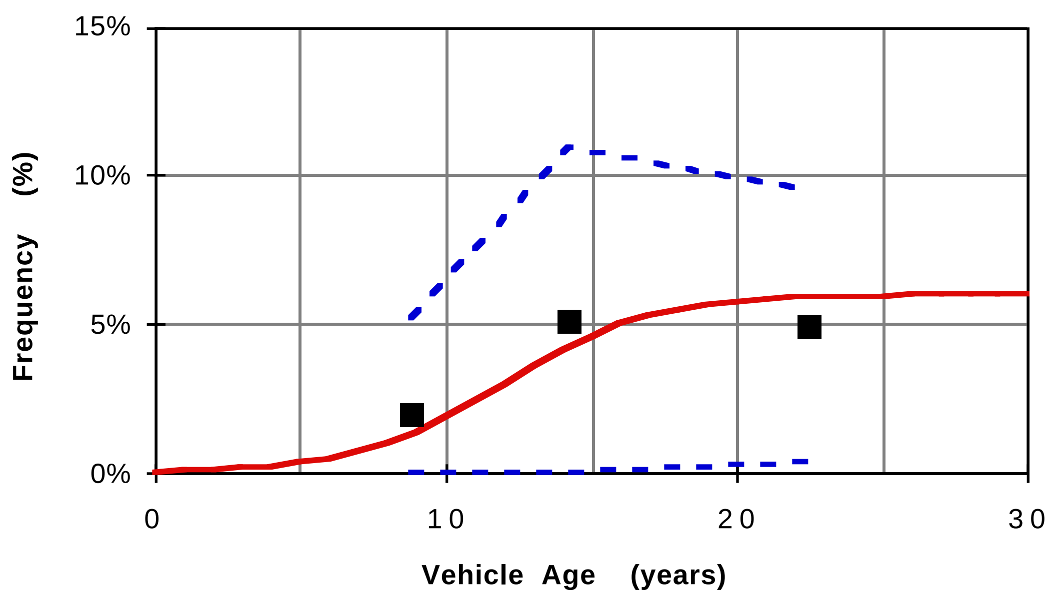
$$\text{Rate of Gross Liquid Leakers Based on Running Loss Testing} = \frac{0.06}{1 + 120 * \exp[-0.4 * AGE]}$$

The predicted occurrences of "gross liquid leakers" based on that equation are also given in Appendix D. The frequencies from Table 3-2 are plotted below in Figure 3-2. Also graphed in that figure are the 90 percent confidence intervals (as dotted lines) from Table 3-2 and the predicted frequencies (as the solid line) from Appendix D (or from the preceding equation). As can be seen (either in Figure 3-2 or by comparing Table 3-2 with Appendix D), the logistic growth curve is within one percentage point of the observed occurrences at each of the three age points. (Also, the predicted frequencies are within 40 percent of the standard deviation of the observed frequencies at each of the three points.)

Again, the newly acquired data (noted at the end of Section 3.1.1) in which no "gross liquid leakers" were found during running loss testing in a sample of 50 late-model year vehicles (mean age of 4.5 years) are consistent with that preceding equation.

Figure 3-2

Predicted Frequency of Gross Liquid Leakers
Based on Running Loss Testing



3.1.3 First Approach Estimating Frequency of Gross Liquid Leakers on the Hot Soak Test

To estimate the rate of occurrence of "gross liquid leakers" on the hot soak test, we first referred to the second assumption on page 15, which states that the collection of vehicles that are "gross liquid leakers" on the hot soak test is the union of the collection of vehicles identified as "gross liquid leakers" on the running loss test with the collection of vehicles identified as "gross liquid leakers" on the RTD test. Thus, we were able to estimate the rate of "gross liquid leakers" on the hot soak test based solely on the rates of "gross liquid leakers" on the running loss and RTD tests. In the last column of Appendix D, the rate of "gross liquid leakers" on the hot soak was calculated by adding the two preceding columns and then subtracting the product of those two columns.

To test the reasonableness of the results of that assumption, we identified the six vehicles (in the hot soak testing program of

300 vehicles conducted for Auto Oil) that had hot soak test emissions in excess of 10 grams per test. In this testing program, the test fleet was again stratified into three model year ranges, but they were different groupings (1983-85, 1986-90, and 1991-93). This resulted in a sample of newer vehicles than were used in the RTD or running loss testing programs.* Those estimated rates of occurrence of the "gross liquid leakers" within each of the three new model year ranges appear below in Table 3-3. The large confidence intervals are again the result of the relatively small sample sizes. We then compared those observed rates (in Table 3-3) with the predicted rates in Appendix D.

Table 3-3

Frequency of Gross Liquid Leakers Based on Hot Soak Testing

Vehicle Age (years)	Sample Size	Frequency	Standard Deviation	90% Confidence Interval	
				Lower	Upper
1.98	66	1.04%	1.25%	0.00%	3.10%
5.55	166	1.20%	0.85%	0.00%	2.60%
9.38	64	6.25%	3.03%	1.27%	11.23%

The observed frequencies from Table 3-3 are plotted in Figure 3-3 (on the following page). Also graphed in that figure are the 90 percent confidence intervals (as dotted lines) from Table 3-3 and the predicted frequencies (as the solid line) from Appendix D. Those predicted occurrences from Appendix D are based <u>not</u> on hot soak test results, but on results of running loss tests and RTD tests.

Comparing, in Figure 3-3, the predicted rates of "gross liquid leakers" occurring with the observed rates of "gross liquid leakers" on the hot soak test, we observe:

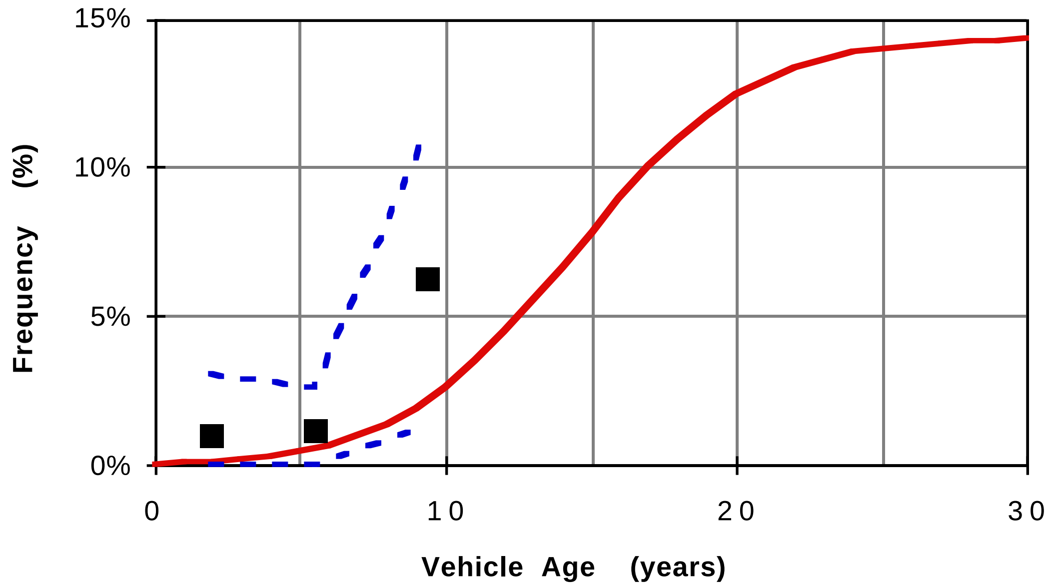
- the predicted rates are all lower than the observed rates which were based on relatively small samples, but
- the predicted rates are all within the 90 percent confidence intervals of the observed rates (at each of the three points).

* Since none of the mean ages in Table 3-3 exceeded 10 years, EPA chose approaches different from those used with the diurnal or running loss emissions. Rather than predicting the occurrence on the hot soak test of "gross liquid leakers" among older vehicles based only on data from newer vehicles, EPA proposes to estimate those rates based on the rates of "gross liquid leakers" on both the RTD an running loss tests.

These differences between the predicted and observed rates may simply be the result of the small sample sizes.

Figure 3-3

Predicted Frequency of Gross Liquid Leakers
On the Hot Soak Test
Based on RTD and Running Loss Testing



Again, the newly acquired data (noted at the end of Sections 3.1.1 and 3.1.2) in which no "gross liquid leakers" were found during hot soak testing in a sample of 50 late-model year vehicles (mean age of 4.5 years) are consistent with the preceding hot soak predictions.

3.2 Second Approach to Estimate Frequency

The second approach employed by EPA was to use all of the observations (in Tables 3-1 through 3-3) to find logistic functions that optimize (simultaneously) all of the predictions. This approach produced the following two equations:

$$\text{Rate of Gross Liquid Leakers Based on RTD/Resting Loss Testing} = \frac{0.0865}{1 + 55 * \exp[-0.259 * AGE]}$$

Rate of Gross Liquid Leakers

$$\text{Based on Running Loss Testing} \quad = \quad \frac{0.058}{1 + 70 * \exp[-0.48 * AGE]}$$

These two equations (and their union which estimates "gross liquid leakers" on hot soak tests) predict rates of occurrence that are all within one-half of the corresponding standard deviations at each of the nine observations (in Tables 3-1 through 3-3). We can again graph those data (i.e., observed rates and confidence intervals) from Tables 3-1 through 3-3, but now in figures with curves from these new predictions (Figures 3-4 through 3-6). The only differences between the three figures in Section 3.1 and these new corresponding figures are the solid lines designating the predicted frequencies.

Figure 3-4

Predicted Frequency of Gross Liquid Leakers
Using Second Approach
Based on RTD Testing

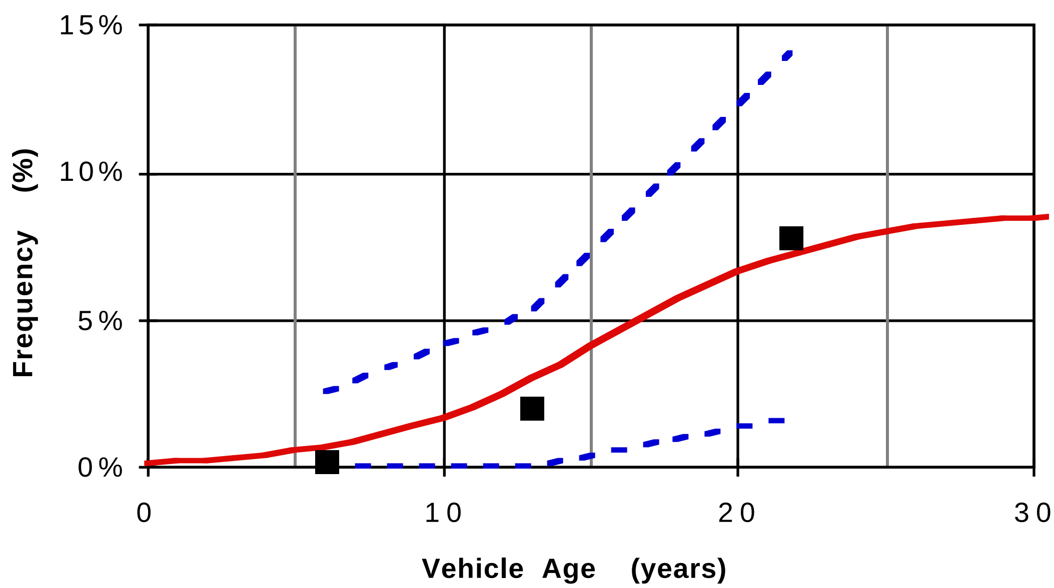


Figure 3-5

Predicted Frequency of Gross Liquid Leakers Using Second Approach Based on Running Loss Testing

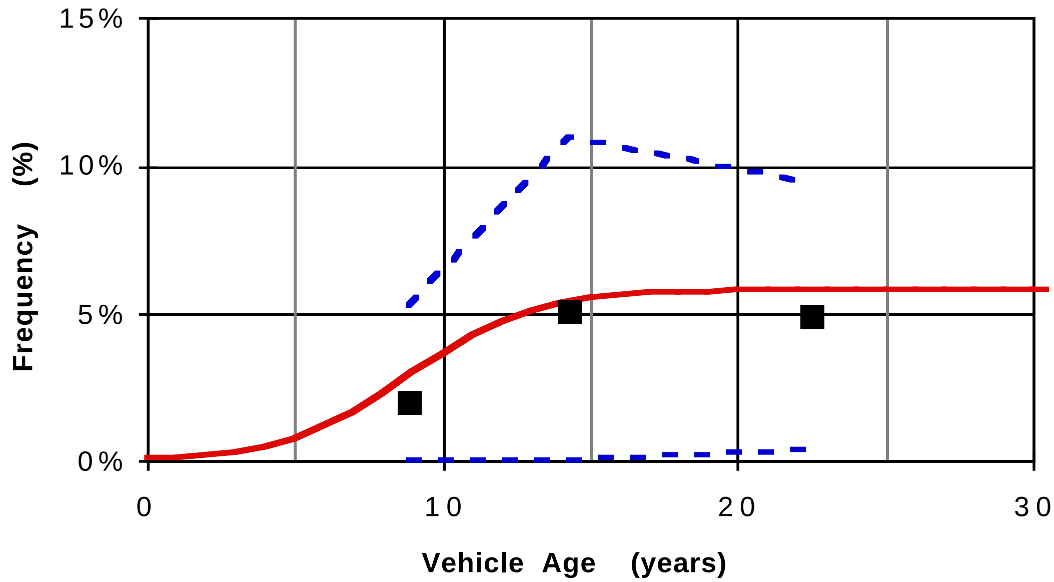
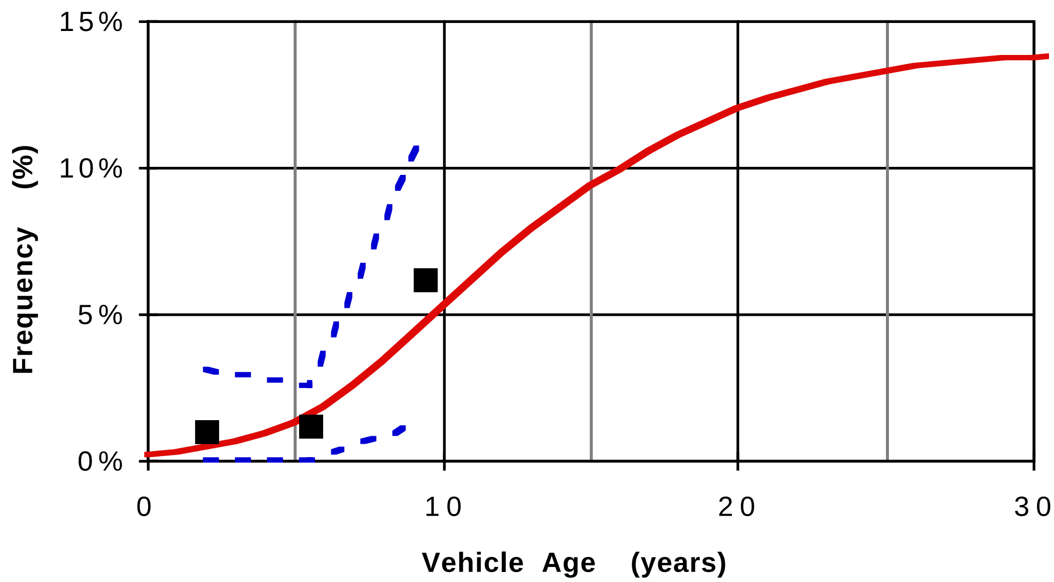


Figure 3-6

Predicted Frequency of Gross Liquid Leakers Using Second Approach On the Hot Soak Test Based on RTD and Running Loss Testing



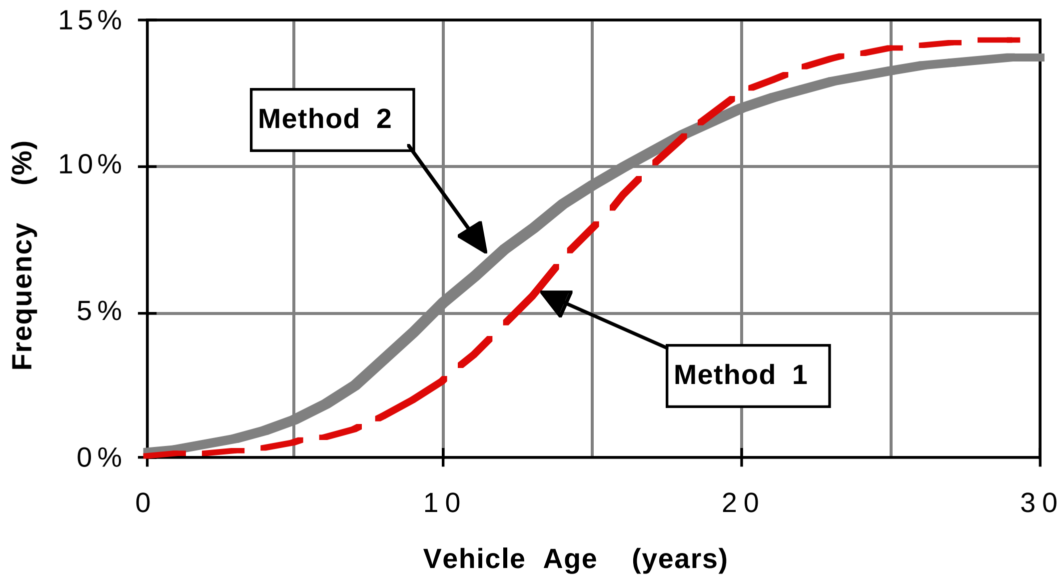
A visual inspection of these three figures (3-4 through 3-6) indicates that this approach produces predicted rates (of the occurrence of "gross liquid leakers") that are all well within the 90 percent confidence intervals of the observed rates (at each of the nine points). In fact (as noted earlier in this section), all nine predict rates are within one-half of the corresponding standard deviations at each of the observations.

3.3 Selection of Approach to Estimate Frequency

In choosing between these two methods (which in EPA's opinion are the two best candidates) of predicting the frequency of "gross liquid leakers," we first observed that the greatest difference between these two methods was in estimating the rate of "gross liquid leakers" on the hot soak test. In the following graph (Figure 3-7), we reproduced the estimated frequency curves from Figures 3-3 and 3-6. In this figure, the "dashed" line is the estimate produced using the first method (i.e., from Figure 3-3 in Section 3.1.3), and the solid line is the estimate produced using the second method (i.e., from Figure 3-6 in Section 3.2).

Figure 3-7

Comparing Predicted Frequency of Gross Liquid Leakers On the Hot Soak Test



A visual inspection of this figure indicates that:

- The two predicted rates are similar for vehicles at least 17 years of age or older.

- For vehicles newer than 17 years of age, the second method predicts a substantially higher occurrence of "gross liquid leakers." (For vehicles up through the age of 10, the second method predicts more than twice as many "gross liquid leakers" as does the first method.)

To decide between these two models, EPA made use of a recent testing program run jointly by the CRC and the American Petroleum Institute (API). This program was specifically designed to determine the frequency of vehicles with liquid leaks. Since actual measurements of evaporative emissions were not performed in this program, we cannot determine which of those vehicles identified as having liquid leaks would have met our criteria for "gross liquid leakers." **[5]**

In that API/CRC program, 1,000 vehicles were inspected for any signs of leaks with the engine operating (during at least a portion of the visual inspection). (This protocol was expected to permit identification of vehicles exhibiting fuel leaks on the RTD, hot soak, or running loss tests.) The vehicles were then classified by the mechanic according to the severity of the observed leaks. The visible liquid leaks were classified as either:

- small liquid leaks (e.g., single drops) or
- larger leaks (e.g., steady flow of drops).

This classification was based on a visual inspection rather than on the results of a test of the actual evaporative emissions. The results of that study are summarized in the following table:

Table 3-4

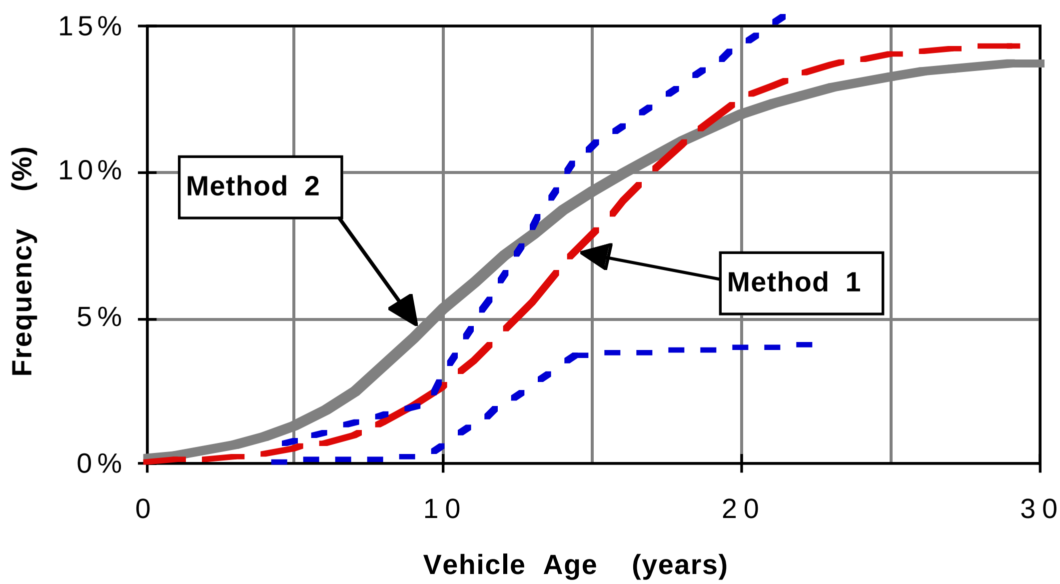
Frequency of Leaking Vehicles In API/CRC Testing Program

Model Year Range	Mean Age (years)	Sample Sizes	Vehicles with Small Leaks	Vehicles with Larger Leaks	Total with Any Leaks	90% Conf Interval Lower	90% Conf Interval Upper
Pre-80s	22.329	70	5	2	7	4.10%	15.90%
80-85	14.394	155	10	1	11	3.70%	10.49%
86-91	9.429	352	2	2	4	0.21%	2.07%
92-98	3.979	423	0	0	0	0.00%	0.49%

The 90 percent confidence intervals in Table 3-4 are based on the (total) number of vehicles with either small or large visible leaks. Those vehicles which were identified as having <u>large</u> visible liquid fuel leaks were almost certainly "gross liquid leakers," and many of the vehicles which were identified as having <u>small</u> visible liquid fuel leaks were possibly "gross liquid leakers" as well. Thus, EPA considers the upper bound of the confidence intervals as a conservative estimate of the occurrence of the "gross liquid leakers." If we reproduce Figure 3-7, and include the 90 percent confidence intervals from Table 3-4 (as dotted lines), we produce Figure 3-8:

Figure 3-8

Comparing Predicted Frequency of Gross Liquid Leakers On the Hot Soak Test



A visual inspection of Figure 3-8 strongly suggests the second method for predicting the frequency of "gross liquid leakers" over predicts the actual occurrence of "gross liquid leakers" for vehicles under the age of 13 years. (The conclusion that the second method "**OVER PREDICTS**" the frequency is based on the results of the API/CRC testing program, primarily the relatively large sample sizes in Table 3-4 compared with those in Table 3-3.)

Therefore, EPA proposes to use the first method (Section 3.1) to estimate the frequencies of the occurrence of "gross liquid leakers" on the three types of tests for evaporative emissions. The results of that method are given in Appendix D.

3.4 Overall Occurrence of "Gross Liquid Leakers" in the In-Use Fleet

The equations in Section 3.1 (or the results in Appendix D) predict the occurrence of "gross liquid leakers" identified on the RTD test to range between 0.02 to 8.55 percent by vehicle age, and for those identified on the running loss test to range between 0.05 and 5.97 percent by vehicle age. It is reasonable to ask what is the overall percentage of these vehicles in the entire in-use fleet. To answer that question, we referred to another report which provides an estimate of the national distribution by age of light-duty vehicles (LDVs) and light-duty trucks (LDTs). (See reference [11].) Applying the percentages from Appendix D to those estimated vehicle counts produces Table 3-5 on the following page. The predicted total counts in Table 3-5 suggest that "gross liquid leakers" represent approximately 1.2 to 1.6 percent of the entire in-use fleet.

Table 3-5

Predicted Occurrence of Gross Liquid Leakers In the National In-Use Fleet of LDVs and LDTs (as of January 1995)

Calendar Year Minus Model Year	Vehicle Counts	"Gross Liquid Leakers" Identified on: RTD	Running Loss
0	9,581,160	2,052.19	4,750.99
1	12,690,223	3,924.61	9,349.56
2	12,595,718	5,621.77	13,760.93
3	12,479,871	8,033.14	20,159.55
4	12,328,489	11,433.59	29,321.45
5	12,124,815	16,178.24	42,197.16
6	11,850,006	22,702.78	59,817.53
7	11,484,110	31,499.85	83,045.60
8	11,007,677	43,050.78	112,104.66
9	10,404,139	57,685.81	145,891.73
10	9,663,040	75,350.55	181,302.31
11	8,783,860	95,286.08	213,090.08
12	7,508,980	111,677.02	226,678.25
13	6,076,245	121,573.75	219,360.63
14	4,896,767	128,727.45	203,502.92
15	3,929,300	131,947.97	181,708.71
16	3,140,650	130,511.75	157,112.78
17	2,503,094	124,468.78	132,479.39
18	2,030,454	116,862.35	111,810.15
19	1,710,242	110,464.75	96,801.22
20	1,451,096	102,385.03	83,696.51
21	1,240,664	93,514.33	72,483.90
22	1,069,132	84,580.52	63,008.21
23	928,705	76,080.74	55,054.76
24 and older	3,724,043	312,764.31	221,641.23
TOTALS:	175,202,480	2,018,378	2,740,130

4.0 References

1) Larry Landman, "Evaluating Resting Loss and Diurnal Evaporative Emissions Using RTD Tests," Report numbered M6.EVP.001, July 1999.

2) Larry Landman, "Modeling Hourly Diurnal Emissions and Interrupted Diurnal Emissions Based on Real-Time Diurnal Data," Report numbered M6.EVP.002, July 1999.

3) Louis Browning, "Update of Hot Soak Emissions Analysis" prepared by Louis Browning of ARCADIS Geraghty & Miller, Inc. for EPA, Report numbered M6.EVP.004, September 1998

4) Larry Landman, "Estimating Running Loss Evaporative Emissions in MOBILE6," Report numbered M6.EVP.008, June 1999.

5) D. McClement, "Raw Fuel Survey in I/M Lanes", Prepared for the American Petroleum Institute and the Coordinating Research Council, Inc. by Automotive Testing Laboratories, Inc., June 10, 1998.

6) D. McClement, "Real World Evaporative Testing of Late Model In-Use Vehicles, CRC Project E-41", Prepared for the Coordinating Research Council, Inc. by Automotive Testing Laboratories, Inc., December 17, 1998.

7) Melvin Ingalls, "Mobile Source Exposure Estimation," prepared by Southwest Research Institute for EPA, EPA Report Number EPA460/3-84-008, March 1984, Appendix A.

8) Edward L. Glover, "Hot Soak Emissions as a Function of Soak Time," Report numbered M6.EVP.007.

9) D. McClement, "Measurement of Running Loss Emissions from In-Use Vehicles (CRC Project E-35)", CRC Report No. 611, Prepared for the Coordinating Research Council, Inc. by Automotive Testing Laboratories, Inc., February 1998.

10) Larry Landman, "Modeling Diurnal and Resting Loss Emissions from Vehicles Certified to the Enhanced Evaporative Standards," Report numbered M6.EVP.005.

11) Tracie R. Jackson, "Fleet Characterization Data for MOBILE6: Development and Use of Age Distributions, Average Annual Mileage Accumulation Rates, and Projected Vehicle Counts for Use in MOBILE6," Report numbered M6.FLT.007.

Appendix A

RTD Emissions of 11 Vehicles with Liquid Leaks With RTD > 30 and Resting Loss > 0.25

(Arranged in Increasing Order of Estimated Resting Losses)

(ALL of the Leaking Vehicles Were Carbureted)

Vehicle Number	Real-Time Diurnal (RTD) (grams / day)	Estimated Rst Loss (at 72°F) (hourly)	Estimated Diurnal (grams / day)
9095	32.26	0.28	24.85
9037	33.44	0.47	21.47
9046	33.76	0.62	18.21
9042	30.88	0.89	8.83
9098	45.21	0.90	22.91
9148	47.97	1.27	16.63
9049	181.35	4.87	64.55
9054	316.59	10.58	62.64
9129	181.79	10.77	Ignore*
9087	478.16	14.12	139.22
9111	777.14	16.51	380.79

* An examination of the hourly RTD data from this vehicle (in reference **[1]**) suggests that the leak actually developed around the tenth hour of the 24-hour test. While the resting loss estimate (based on hours 19 through 24) is most likely valid, the estimate of diurnal emissions is unreliable.

Note that while <u>all</u> 11 of these vehicles are liquid leakers most of them do <u>not</u> qualify as "<u>gross</u> liquid leakers."

Appendix B

Hot Soak Emissions of 14 Vehicles with Liquid Leaks (With Hot Soak Emissions At Least 2.0 grams / test)

Sorted by Fuel Delivery System In Increasing Order of Emissions

Program	Vehicle Number	Fuel System	Temp (°F)	RVP (psi)	Hot Soak (grams HC)
Auto Oil	134	CARB	94	6.0	2.54
EPA	177	CARB	95	6.1	4.63
EPA	122	CARB	105	6.1	5.53
Auto Oil	79	CARB	92	7.0	9.49
EPA	173	CARB	92	6.7	14.53
EPA	97	CARB	110	6.7	14.66

Program	Vehicle Number	Fuel System	Temp (°F)	RVP (psi)	Hot Soak (grams HC)
EPA	143	TBI	94	6.4	8.28

Program	Vehicle Number	Fuel System	Temp (°F)	RVP (psi)	Hot Soak (grams HC)
Auto Oil	35	PFI	104	6.7	2.00
Auto Oil	199	PFI	96	6.5	2.26
Auto Oil	47	PFI	93	6.1	11.56
EPA	33	PFI	113	6.0	46.95
Auto Oil	276	PFI	87	6.3	49.39
EPA*	372	PFI	106	9.0	54.18
EPA*	266	PFI	105	9.0	88.57

* These two vehicles were tested using a substantially more volatile fuel.

Appendix C

Running Loss Emissions of 10 Vehicles with Liquid Leaks (With Running Loss Emissions At Least 5.0 grams / mile)

(Arranged in Increasing Order of Estimated Resting Losses)

(ALL of the Leaking Vehicles Were Carbureted)

Vehicle Number	Running Loss HC (grams / mile)	Running Loss HC (grams / LA-4)	Running Loss HC (grams / hour)
35044	5.009	37.47	98.32
35125	5.297	39.44	103.49
35099	5.649	42.17	110.65
35085	6.880	51.18	134.29
35045	7.469	55.79	146.39
35071	9.175	68.84	180.63
35047	13.480	100.19	262.89
35129	13.566	100.72	264.28
35054	24.841	184.96	485.32
35091	42.973	318.90	836.76

Appendix D

Predicted Frequency of Occurrence of "Gross Liquid Leakers"

Vehicle Age (years)	Resting Loss / Diurnal	Running Loss	Hot Soak
0	0.02%	0.05%	0.07%
1	0.03%	0.07%	0.10%
2	0.04%	0.11%	0.15%
3	0.06%	0.16%	0.23%
4	0.09%	0.24%	0.33%
5	0.13%	0.35%	0.48%
6	0.19%	0.50%	0.70%
7	0.27%	0.72%	1.00%
8	0.39%	1.02%	1.41%
9	0.55%	1.40%	1.95%
10	0.78%	1.88%	2.64%
11	1.08%	2.43%	3.48%
12	1.49%	3.02%	4.46%
13	2.00%	3.61%	5.54%
14	2.63%	4.16%	6.67%
15	3.36%	4.62%	7.83%
16	4.15%	5.00%	8.95%
17	4.97%	5.29%	10.00%
18	5.75%	5.51%	10.94%
19	6.46%	5.66%	11.75%
20	7.05%	5.77%	12.42%
21	7.54%	5.84%	12.94%
22	7.91%	5.89%	13.34%
23	8.19%	5.93%	13.63%
24	8.40%	5.95%	13.85%
25	8.55%	5.97%	14.00%